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Sewage Gone Green

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Abstract

The Mbaracayu Forest Reserve School in Paraguay lacks an adequate sewage processing system. However, many modern techniques for producing clean effluent utilize expensive and environmentally damaging chemicals. A more sustainable alternative exists by using naturally occurring macrophytes and microbes to purify raw sewage. Through literary research and working with Martin Burt of the Fundacion Paraguaya, sponsor of this project, we designed a parallel lagoon system that uses water hyacinth and natural processes to create clean effluent which is discharged away from the community. Raw sewage enters the system at an elevated position and is slowly driven by gravity through a series of lagoons with different functions and processes that reduce nitrogen, phosphorus, TSS, BOD, and pathogens from the sewage to acceptable levels. The flow is controllable by manually operated gates. The parallel lagoons are interconnected by pipes and operable gates to allow parts of the system to be by-passed for maintenance or in case of malfunction. In addition to producing safe effluent, this system creates two sustainable agricultural resources for the school in sludge and water hyacinth. The sludge can be used as a fertilizer rich in organic material and nutrients including phosphorus and nitrogen. Water hyacinth can be utilized as compost, animal feed, rope, and for paper fabrication. This solution will provide the Mbaracayu school with necessary sewage treatment and two sustainable resources for agriculture while hopefully providing a template to other communities in developing countries across the world.

Objectives

- Design a sustainable sewage processing system that only uses natural biological processes and organisms to create safe effluent
- Capacity to absorb and process the waste of 250 people per day
- Provide a sucessful solution that inspires other communities to adopt similar systems

Problem: No sewage processing system at the Mbaracay Forest Reserve School

The current system: 3 unused and small tenches

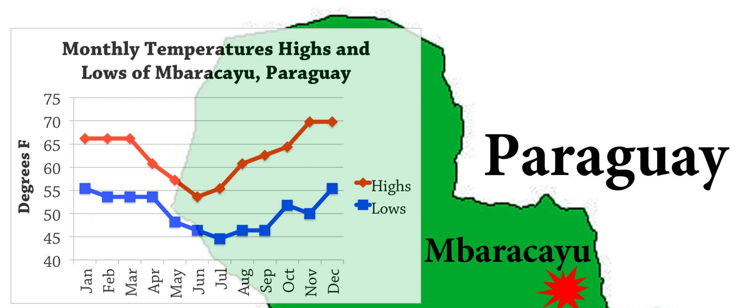
- Current working system is under capacity
  - 1300 gallon septic tank
- Architect created a "green" sewage system that is no longer in use
  - 3 12x1x1 meter trenches with assorted plants
  - Insufficient size: 10,000 gallon capacity
  - Did not produce clean effluent

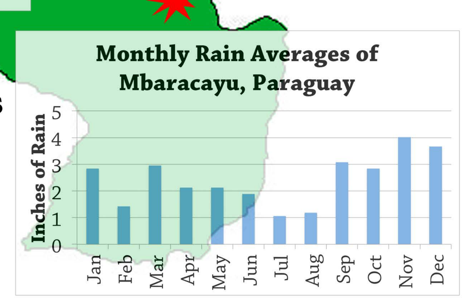
How it Works

- Raw sewage enters primary treatment and proceeds through the system over 7-8 days, being purified at each step
  - Gravity fed
- Water flow is controlled by adjustable weirs that also aerate the system
- Parallel ponds are connected by gates to allow bypass of lagoons for maintenance or in case of malfunction

Research

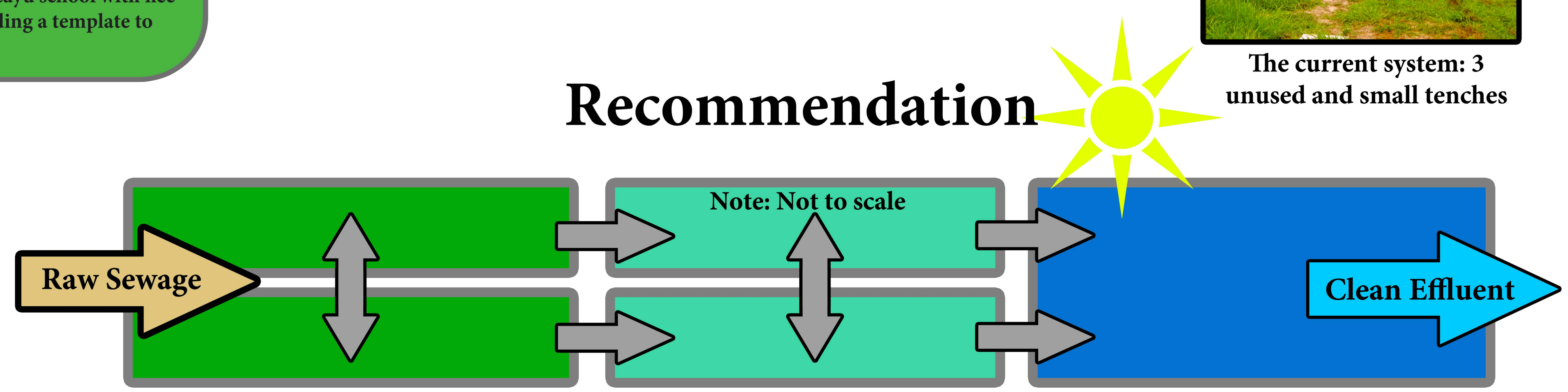
Climate





Conclusions:
- A wide variety of plants can survive in the temperature range
  - Never freezes
- Moderate rain

Recommendation



Primary Treatment

- 2 25 x 2 x 1 meter lagoons with water hyacinth
- Suspended solids settle
- Water hyacinth
  - Remove ~60% N & P
  - Reduce BOD
- Minor microbial decomposition
- Each lagoon has a 2.5 day detention period

Secondary Treatment

- 2 20 x 2 x 1 meter lagoons with water hyacinth
- > 95% TSS reduction
- Water hyacinth provide a substrate for microbes
- Microbes
  - Aeration enables breakdown of organic solids
- 2 Day detention period (x2)

Maturation Pond

- 30 x 4 x 0.5 meter lagoon devoid of plant life
- Exposes effluent to sunlight
  - UV light kills bacteria
- 3 day detention period
- Discharges safe effluent

System Size

- Estimated 5000 gal/day
  - 250 people x 20 gallons/day
- Total capacity: 63,000 gallons
  - 12 days
- Lagoon Area: 300 m^2

Sewage Breakdown

Role of Plants:

- Absorb N & P through growth
- Provide a substrate for microbial growth
- Add oxygen, reducing BOD

Role of Microbes:

- Decompose solids and sludge into simple organic compounds
  - Reduce BOD and TSS
- Requires oxygen
  - Most effective when aerated
- Aeration
  - Mechanical pumps
  - Falling water oxygenates

Maintenance

Sludge Removal

- All lagoons require periodic intervals of sludge removal
  - Frequency depends on lagoon and data collected
- Procedure:
  - Water is drained into the neighboring/next lagoon
  - Sludge is manually removed by workers
- After removal, sludge can either be dewatered and applied as liquid fertilizer or composted

Water Hyacinth

- To ensure optimal nutrient removal high water hyacinth growth is necessary
- Constant harvesting of water hyacinth prevents overcrowding and provides a sustainable resource (est. 45 wet tons/year)
- Water Hyacinth uses:
  - Animal feed, fertilizer, paper

Construction

- Manual excavation with local workers and contractors ($12/day)
- If system size and design are final, the lagoon walls will be concrete
  - Otherwise, a plastic liner will prevent seepage and groundwater contamination

Water Hyacinth

- Free-floating aquatic plant with large leaves and flower
- Reproduces asexually through runners and sexually through seeds
- Rapid reproduction
- Already present in Mbaracayu
- Able to survive significant N & P fluctuations
- Proven effective in systems from San Diego to Thailand
- Can be used for animal feed, fertilizer, and paper

Evaluating System Effectiveness

- Test effluent for TSS and pathogens
  - Procedures for N & P are too expensive
  - BOD test requires chemicals and training
- TSS: Filter a water sample and measure the weight of solids left behind
- Pathogens: Coliform testing kit
  - Culture water sample and dye to reveal coliforms, pathogen indicators

Acknowledgements

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Next Steps

- Better determine system size
  - Measure daily sewage inflow
- Implementation
- Continuous improvement
- Collect data to optimize:
  - System effectiveness
  - Sludge removal
  - Hyacinth harvesting